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Polarized beams for applications in chemistry and biology, and soon medicine

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This talk tells the story of how we are applying polarised radionuclei not only in nuclear physics and fundamental-interaction studies, but now also in chemistry and biology, and soon also in medicine. The common point of these versatile studies is the fact that beta or gamma decay from polarized radioactive nuclei is anisotropic in space.
Our experimental setup devoted to laser polarization of short-lived nuclei [1] is located at the CERN-ISOLDE facility, where over 1300 different isotopes are available for research. Since its commissioning in 2016, we have already used it to polarize 35Ar beam with the aim to determine more precisely the Vud matrix element of the CKM quark mixing matrix [2]. Soon, we plan to perform nuclear structure studies by measuring angular beta-gamma coincidences in order to assign spins and parities of nuclear excited states in regions of the nuclear chart, where observations are especially challenging for nuclear theory [3].
The transfer of our expertise to chemistry and biology concerns beta-detected Nuclear Magnetic Resonance (NMR), which is up to 10 orders of magnitude more sensitive than conventional NMR [3]. This is thanks to a much higher degree of spin polarization and a much more efficient resonance detection via beta-decay asymmetry. We aim at using it for the studies of the interaction of proteins and DNA with metal ions, such as Na, Cu, Zn, which are crucial in many biological processes, including Alzheimer's and Parkinson's diseases. The first studies concern Na interaction with DNA G-quadruplex structures [4]. A further development concerns gamma-detected Magnetic Resonance Imaging (MRI), which can combine the strengths of the high sensitivity of PET and SPECT techniques with high spatial resolution of MRI by using polarized beams of longer-lived gamma-decaying nuclei. The first nuclei we aim at polarizing here are long-lived isomers of Xe [5].
In this talk I will introduce asymmetry of beta and gamma decay, will mention principles of laser polarization and the experimental setup, and will concentrate on the first applications of beta-NMR in chemistry and biology and gamma-MRI in medical diagnosis.

[1] M. Kowalska et al., J. Phys G. 44 (2017) 084005; W. Gins et al., Nucl. Instr. and Meth. A 925, 24 (2019), https://doi.org/10.1016/j.nima.2019.01.082
[2] W Gins, PhD Thesis (2019), KU Leuven, https://cds.cern.ch/record/2654181?ln=en
[3] M Madurga, M Kowalska, et al., ISOLDE Scientific Proposal (2017) https://cds.cern.ch/record/2288198?ln=en
[4] M Kowalska et al, ISOLDE Scientific Proposal (2018), https://cds.cern.ch/record/2299798?ln=en
[5] R. Engel, master thesis, U Oldenburg, https://cds.cern.ch/record/2638538?ln=en

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